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States
ment of
Agriculture

Forest Service

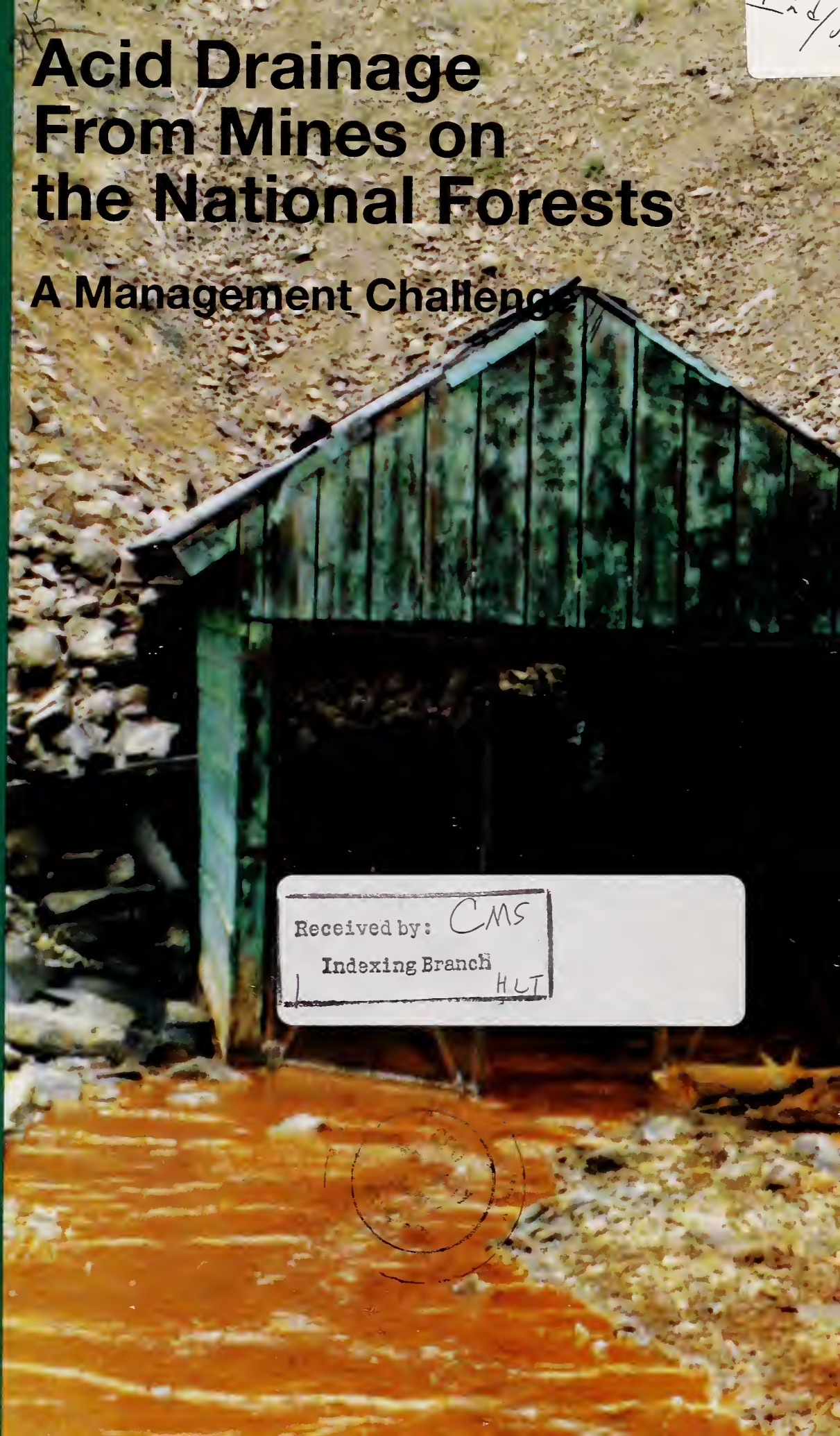
In Cooperation
with the U.S.
Department of
the Interior's
Bureau of Mines

Program Aid 1505

March 1993

Acid Drainage From Mines on the National Forests

A Management Challenge



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On the Front Cover

Old mine adit on the Rio Grande National Forest in Colorado. Although partially collapsed, this adit still drains a historic lead, copper, and zinc mine. High acidity and high metal content have severely affected aquatic lifeforms below the mine.

All photos USDA FS/WO–M&GM

"The Forest Service has identified acid drainage from mine sites as the most difficult and costly reclamation problem it faces with western metalliferous mining operations . . . with some significant environmental problems dating as far back as the late 1800's."

When the cooperative research plan on acid drainage from mine sites was signed in April 1991 by the Bureau of Mines and the Forest Service, its mandate was clear—to provide and apply technology to help manage national forests and grasslands affected by acid drainage. The plan represents a long-term cooperative research program focusing on National Forest System lands in the Western United States being carried out using the Research, Development, and Application (RD&A) model. It is a comprehensive program with practical goals—to provide and make use of needed information.

Under the program:

- The Bureau of Mines provides information on the prediction, control, and treatment of acid drainage from mine sites.
- The Forest Service, the mining industry, and others provide research sites and use the information.
- The Forest Service monitors its effectiveness.

This report highlights program contributions to be achieved over time. It also summarizes contributions of the program to date and describes how the program functions. The current effort is a long-term one, using available resources. Additional resources specifically designated to this cooperative effort would result in accomplishing the work in a more timely fashion.

Of course, the true effectiveness of the acid drainage cooperative research program will not be known for some years. Applying the results of new research and development is not accomplished quickly—it takes time. Fortunately, application of this new information being provided by the Bureau of Mines will be a continuing part of Forest Service programs.

Figure 1
Mine tailings producing acid drainage on the Prescott National Forest in Arizona. This gold, lead, and zinc was active in the 1890's.

The Forest Service and the Bureau of Mines –*Agency Responsibilities*

The U.S. Department of Agriculture's Forest Service and the U.S. Department of the Interior's Bureau of Mines each has unique responsibilities in the management of mineral resources in the United States. Generally, the overall responsibility for managing federally owned minerals belongs to the Bureau of Land Management. Other Department of the Interior agencies have minerals responsibilities as well.

In part, the Forest Service is charged with administration and management of National Forest System lands, including land and resource management planning. This responsibility encompasses the mining and extraction of mineral resources, the approval of mining and reclamation plans that protect the environment, particularly surface resources, and the research necessary to protect these resources. The Bureau of Mines has responsibility to ensure that the United States has a dependable and secure supply of domestic minerals, to conduct investigations and research for this purpose, and to protect the environment and minimize damage due to mining and mineral processing activities.

In June 1990, the two agencies entered into a Memorandum of Understanding to enable them to develop and carry out a comprehensive research program to solve problems and demonstrate solutions to acid drainage problems on National Forest System lands. It is an important program, in that solutions to problems such as these are necessary for the extraction of mineral resources in an environmentally sensitive manner. In effect, it influences the degree to which minerals necessary for the economic viability of the Nation are available on these lands.

"The Forest Service and Bureau of Mines have entered into a Memorandum of Understanding to enable them to develop and carry out a comprehensive research program to solve . . . acid drainage problems."

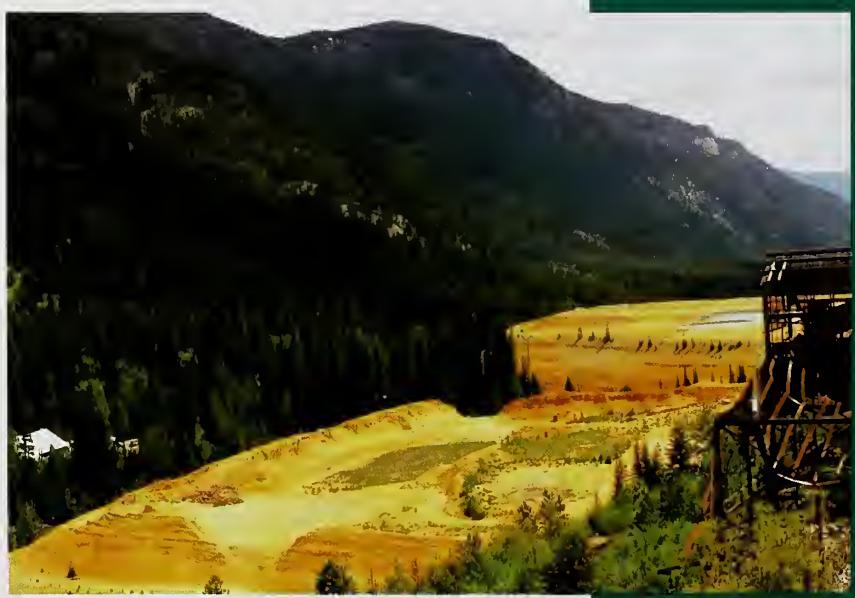

Figure 2
Acid is generated from these abandoned mill tailings on the Wenatchee National Forest in Washington. The primary commodity was copper. The color of the tailings results from precipitated iron.

The Problem

The Forest Service has identified acid drainage from mine sites as the most difficult and costly reclamation problem it faces with western metalliferous mining operations. Acid drainage persists at many active and abandoned mine sites, with some significant environmental problems dating as far back as the late 1800's. There are also concerns that current and future mining operations may generate acid drainage for years or decades after the mines cease operation. Unfortunately, major technical uncertainties are associated with the prediction of acid drainage potential at the time of mine plan approval as well as with mitigation or treatment techniques for post-mining use.

Over 1,500 western mining sites with significant acid drainage problems have been identified on National Forest System lands. Many of these sites in remote locations that are not accessible the year around often represent small, but ecologically damaging flows. Such sites require either permanent control measures to prevent or mitigate acid formation, or low-cost, passive treatment technology to neutralize and detoxify the waters. The problems of acid drainage from the sulfide-bearing rock present at many western metal mines are exacerbated by contamination that occurs when acid waters contact exposed mineral zones and dissolve heavy metals. Many of these metals are toxic to aquatic and terrestrial life, if the concentrations are high enough.

Forest Service land managers, who face increasingly complex and controversial decisions regarding mineral development, need new research information. One major problem affecting the future of metal mining in the West is the absence of technology to predict the potential of new mining ventures to generate acid drainage. State and Federal permitting and regulatory agencies need information on the acid-forming potential of ore deposits in order to analyze the impacts of new mining operations and provide for the development of necessary environmental controls. Gold and other precious metal operations, which have experienced a 30- to 35-percent growth in domestic production in each of the last 5 years, are expected to continue. Without additional research information, it is almost certain that a significant percentage of existing and new mining ventures will experience unexpected acid drainage situations. These situations could result in expensive and difficult remedial actions to prevent adverse environmental impacts, primarily to surface and ground waters, due to metal-contaminated drainage.

The fact that acid drainage has been a persistent problem for more than 100 years is indicative of one of the major difficulties in dealing with it—that there are currently no widely applicable technologies to mitigate or stop a fully developed acid drainage situation. Only stopgap prescriptions are available and at considerable cost. On the other hand, the application of State and Federal regulatory controls on some modern mines has, in some instances, been able to limit the development of acid mine drainage and consequently reduce the long-term environmental effects. However, regulatory controls do not always work. In the case of old, abandoned mines it is too late for regulatory controls. New technologies are needed to effectively deal with these problems.

Currently, reliable data on the total number of mines producing acid drainage and on the number of miles of streams affected by acid and metal drainage are not available for the Western United States. However, various estimates have placed the number of these mines in the range of 20,000-50,000, seriously affecting 5,000-10,000 miles of streams. The cumulative effect of these mines, whatever their actual number, is significant.

The basis for the production of acid drainage is well understood. Pyrite and other sulfide minerals are exposed to air and water in the mining process. Air and water oxidize the sulfide minerals, releasing sulfuric acid and sulfates. This process is catalyzed by iron-oxidizing bacteria and permits a host of site-specific secondary reactions, principally ion exchange and acid-induced metal dissolution. The metals that may be involved in this process cover the range of heavy metals: arsenic, cadmium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc. Once the chemical reactions are fully realized, the discharge of acid and metal ions is known to persist

Please Note:

States in solid color are the ones represented by photos in this publication. However, acid drainage from metal mines is a problem throughout the West.

A sampling of national forests having acid drainage problems. Numbers refer to figure numbers in this publication.

in some cases for hundreds of years and should be considered a long-term source of contamination. Although this process does occur naturally, it is the volume of drainage from mine sites that is problematic.

The makeup of acid drainage varies from mine to mine and from location to location. Classic acid drainage is composed of acid, precipitated iron compounds, sulfate ions, and dissolved metals. It is the metals, far more than the acidity, that cause the environmental damage. The type of metals in acid mine drainage is controlled by the mineralogy of the ore body; lead and zinc mines may produce metal migrations of lead and zinc. Unexpectedly, gold mines may produce flows containing arsenic. Once the acidity and metal ions migrate into the soils, they are usually unable to support the normal complement of vegetation and soil fauna and flora. These biological components of the soil are inhibited by the dissolved metals in the soil water solution. Bare, unvegetated soils are eroded by the weather elements, and streams are physically contaminated with large volumes of metal-bearing sediments coming off the acidified upland areas of the mines. Extant groundwater aquifers may also be contaminated by the dissolved metals.

When acid and metal drainage enters streams, the fish and other stream organisms are often depleted in a relatively short period of time. Copper ions are especially lethal to fish, but not to mammals. In a coldwater fishery, in softwater conditions, a copper concentration of as little as one part per million may be lethal to trout. Streamside vegetation is affected by a change in species composition and exhibits a general loss of vigor. However, some lower quality streamside vegetation is usually retained.

To briefly summarize, flows of acid drainage often create large, toxic, metal-bearing sediment loads in stream channels. The channels may be brightly colored—red, purple, and orange—by precipitates of iron and other metal compounds. The waters are somewhat acidified, but the metal constituents may increase drastically. Fish and other organisms in the system are lost in the waters most affected as a result of the metal contamination. Streamside vegetation is often changed as to species composition and loss of vigor. The most seriously affected streams are considered to be "dead." Ground water may also be contaminated with metal ions.

A Model of Cooperation

"Without additional research . . . it is almost certain that a significant percentage of existing and new mining ventures will experience unexpected acid drainage situations that could result in expensive and difficult remedial actions . . . ."

The current gold boom in the Intermountain West began in the mid 1980's. It was made possible by a combination of high precious metals prices; discovery of large, low-grade, disseminated ore deposits; and new extraction technology. By the close of the decade, the Forest Service and some segments of the mining industry had recognized the need for better research information to deal with the likelihood of acid drainage. Acid drainage research and development efforts were generally not well coordinated with the needs of the national forests, and adequate planning for this type of focus was often lacking. For this reason, effective June 6, 1990, a Memorandum of Understanding was signed by the Bureau of Mines and the Forest Service in which the two agencies mutually agree to cooperate in addressing the significant national problem posed by acid drainage from mine sites in the Western States. The agreement does not include funding considerations.

A joint agency working group established by the agreement has identified four priority areas that must be addressed to develop effective solutions to acid drainage problems in the West. Together, these areas make up the cooperative research program. They relate to (1) predictive techniques and methodologies to assess the potential of new mining ventures to generate acid waters; (2) control technologies to prevent or minimize acid drainage; (3) treatment technologies to mitigate existing acid drainage problems; and (4) technology transfer and program monitoring to assess the effectiveness of technologies in the above three areas and transfer the information to the mining industry and government agencies.

Under the direction of the national offices of the Forest Service and the Bureau of Mines, the joint agency working group is responsible for program planning, setting research priorities, identifying field study and demonstration sites, and information exchange.

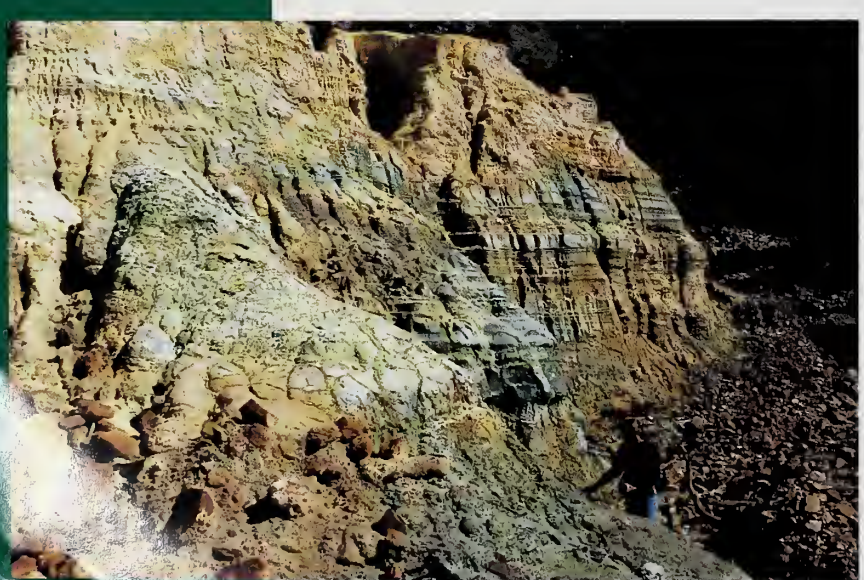

Figure 3
Eroded mine and mill tailings generate acid on the Coronado National Forest in Arizona. The operation produced copper, silver, gold, and other metals.

The cooperative **research** program is a shared effort between the Bureau of Mines and the Forest Service. Basic research information forms the technical foundation of any such program. Although much new technology needs to be generated for the Western United States, some technology is already available in the East upon which to build. Much attention has been directed at acid problems associated with eastern coal mines. In fact, the Bureau of Mines has had an active research program to address acid drainage from eastern coal mines for more than 20 years and has produced a number of successful reclamation, mitigation, treatment, and pre-mine prediction technologies.

Development involves molding existing knowledge and technology into a form that can be used in specific ways. In this case, development efforts will utilize the knowledge base on treatment of acid drainage from eastern coal mines and the extensive expertise of the Bureau of Mines in mining and processing of oresfrom western metal mines. Research and development in this RD&A model is being accomplished by the Bureau of Mines with Forest Service support.

Effective **application** of the cooperative model involves successful technology transfer. Unfortunately, considerably greater emphasis is frequently placed on generating information than on transferring it to users and getting it applied. As a result, a great disparity can exist between the amount of information available and the amount used. In this model, technology transfer is being emphasized and includes usage of the information on the ground. Monitoring to determine the effectiveness of new technologies is considered an integral part of application. The Forest Service, because it administers the land and regulates mining activity, has responsibility for application of research and development information with Bureau of Mines support.

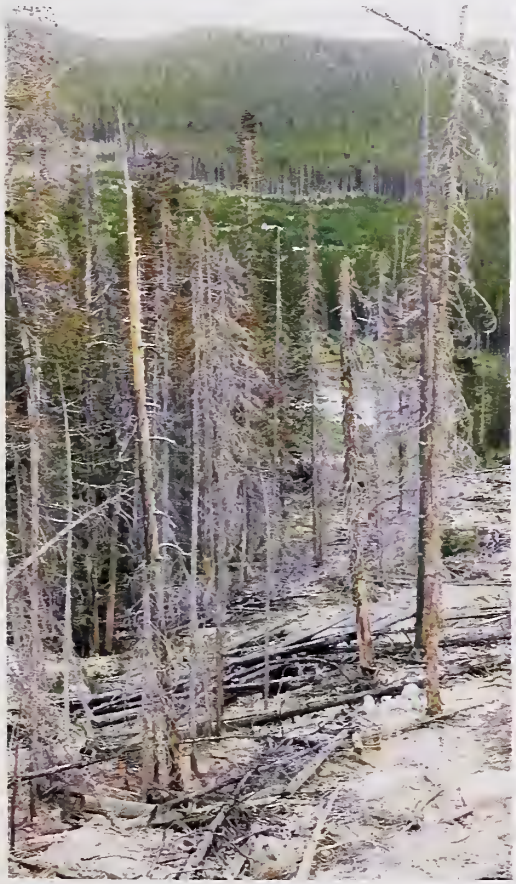

Figure 4
Trees killed by heavy-metal-contaminated acid drainage seeping from sulphide-bearing waste rock on the Helena National Forest in Montana. The mineral commodity was gold.

Figure 5
Acid rock drainage seeps from an abandoned mine adit on the Boise National Forest in Idaho. This water has unusually high concentrations of arsenic.

The Solution

The real value of a cooperative research program depends on its ability to accomplish specific objectives in a given period of time. In addition, the speed at which a program functions is directly related to the resources allocated to it. Therefore, ideally, information and technologies to solve acid drainage problems from mines on National Forest System lands should be generated quickly, followed by a period during which agencies and the mining industry focus on implementing the solutions. The RD&A approach allows for concentration on high-pay-off projects that would otherwise not be accomplished. Following is an explanation of the four priority research areas:

". . . development of effective techniques and methods for predicting the potential of new mining ventures to form acid drainage. . . . would allow the Forest Service, other land management agencies, and industry to avoid repeating the mining mistakes of the past . . . ."

Figure 6 *(Background Photo)*
Acid rock drainage from abandoned gold mine workings in Montana. This mine on the Deerlodge National Forest had both underground and open pit activity.

Figure 7
A stream damaged by acid mine drainage in Montana, Lewis and Clark National Forest. Note the red color from iron precipitate on the stream bottom.

Acid Drainage Prediction

Scope: The Forest Service and the Bureau of Mines concur that the development of effective techniques and methods for predicting the potential of new mining ventures to form acid drainage is one of the highest priority efforts of cooperative research. In essence, predictive technologies would allow the Forest Service, other land management agencies, and industry to avoid repeating the mining mistakes of the past that have led to acid drainage problems. An accurate assessment of the potential for acid drainage formation using information obtained during exploratory drilling, for example, could be used in the permitting process. In addition, the assessment would allow industry to design mine and waste management plans to prevent or mitigate adverse environmental impacts from acid drainage.

Objective: Within 5 years, develop quantitative models, techniques, and methods for the prediction of acid drainage from samples obtained from exploratory drilling programs.

Control Technologies for Acid Drainage

Scope: There is a need for more effective technologies to control acid drainage at both abandoned and operating mine sites. Control aims to prevent acid drainage formation by inhibiting the weathering processes, for example, by preventing water or oxygen contact with mine wastes or mine workings. This technology is applicable to past sites and to all new operations through the development of mine and waste management plans.

Objective: Develop and demonstrate a suite of economical techniques that limit effluent volumes or heavy-metals concentrations from mines and waste rock (nonpoint sources of pollution). These include underground mine workings and pits, coarse waste rock, and fine fractions of mill wastes.

Treatment Technology for Acid Drainage

Scope: Cost-effective technology is needed to correct acid drainage from past operations. The development of a low-maintenance or passive treatment process may be the only cost-effective solution for many national forest sites because of their location, low-volume discharge, or extensive and diffuse underground contamination source. Research should focus on developing low-cost chemical and biochemical systems for small-volume discharges that can operate with minimum maintenance.

Objective: The 5-year objective is to develop a passive, low-maintenance system or systems for treating low-volume drainage from mine adits (point sources of pollution). Treatment may involve combined passive systems, which ideally would produce dense and environmentally stable sludges and have the potential for metal recovery to limit disposal costs.

Program Monitoring and Technology Transfer

Scope: The need to determine the effectiveness of new acid drainage technologies has resulted in a commitment on the part of the Forest Service and the Bureau of Mines to carry out long-term monitoring in the above three research areas. In addition, improved knowledge and technologies to predict, control, and treat acid mine drainage will require aggressive technology transfer, training, and information sharing efforts.

Objectives: Develop and carry out long-term monitoring and evaluation plans consistent with the level of new methods and techniques. Enhance the awareness of acid drainage problems and solutions with the mining industry and State and Federal land management and regulatory agencies.

Benefits

". . . application of this new information being provided by the Bureau of Mines will be a continuing part of Forest Service programs."

The benefits of an effective RD&A program include:

- The ability to predict the potential for acid drainage from mine sites will enable land managers to make informed decisions regarding the exploitation of metallic mineral resources on public lands.
- Predicting the likelihood of acid drainage prior to mining will enable industry to design effective control and mitigation measures into the mining operation.
- The economic viability of the mine can be better assessed. This will reduce premature and ineffective closure due to unexpected environmental control costs.
- A better design for final mine closure can be prepared. Post-mining site monitoring will be reduced, and the time for monitoring will be shortened.
- New techniques will prevent or reduce acid discharges from metal mines and processing wastes. Elimination of these discharges will preclude or reduce acid and heavy metal pollution of receiving streams and ground waters.
- Improved drinking water supplies and restoration of acquatic habitat will result. There will be an elimination of visual pollution of streams due to precipitation of iron compounds.
- Reduced costs for waste water treatment and correcting other damage to the environment.

Figure 8
Highly acidic tailings, with high metals content, were released downstream following collapse of a tailings dam on the Rio Grande National Forest in Colorado.

Accomplishments To Date

Program accomplishments as coordinated by the joint agency working group include:

- Development of site selection criteria for cooperative Bureau of Mines / Forest Service research-related efforts.
- Establishment of a joint agency reconnaissance team for site evaluation and selection.
- Assistance in the control and treatment of acid drainage from the Golinsky Mine on the Shasta-Trinity National Forest.
- Sponsorship of and participation in a national acid mine drainage seminar for industry, land managers, and State and Federal regulatory agencies.

Figure 9
Acid drainage from an inactive gold mine runs down this hillside on the Shasta-Trinity National Forest in northern California. The acid flow has been the cause of fish kills further downstream.

Obviously, these accomplishments represent only a beginning and reflect limited funding. Much work remains to be done. The Forest Service and the Bureau of Mines are committed to moving ahead in this important work as fast as possible. The alternative to solving these problems at the pre-mining or mining stages of mineral development could result in unacceptably long long-term commitments to water treatment and site cleanup. In this age of environmental awareness, this alternative is of course unacceptable for current and future mining operations. Long-standing acid drainage problems from mines in the forests, many from operations before the national forests were set aside, are also in the public eye, with the expectation that an aggressive cleanup program will be pursued. The actions outlined in this publication are consistent with that expectation and are supported by the mining industry.

Figure Ten
Hillsides affected by mining in central California, Toiyabe National Forest. The acids generated in the soils of this old sulfur mine have severely slowed the rehabilitation of the area.

A cooperative interagency effort . . . aimed at solving acid drainage problems.